Global Land Data Assimilation System (GLDAS) Products, Services and Application from NASA Hydrology Data and Information Services Center (HDISC)

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ABSTRACT

The Global Land Data Assimilation System (GLDAS) is generating a series of land surface state (e.g., soil moisture and surface temperature) and flux (e.g., evaporation and sensible heat flux) products simulated by four land surface models (CLM, Mosaic, Noah and VIC). These products are now accessible at the Hydrology Data and Information Services Center (HDISC), a component of the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC). Current data holdings include a set of 1.0 degree resolution data products from the four models, covering 1979 to the present; and a 0.25 degree data product from the Noah model, covering 2000 to the present. The products are in Gridded Binary (GRIB) format and can be accessed through a number of interfaces. Users can search the products through keywords and perform on-the-fly spatial and parameter subsetting and format conversion of selected data. More advanced visualization, access and analysis capabilities will be available in the future. The long term GLDAS data are used to develop climatology of water cycle components and to explore the teleconnections of droughts and pluvial.

INTRODUCTION

Global hydrological data such as soil moisture and evaporation are crucial for understanding the land surface process and the atmospheric general circulation modeling for climate simulation and weather forecasting. The Hydrologic Sciences Branch (HSB) at NASA's Goddard Space Flight Center (GSFC) has collected a series of surface hydrological data sets in order to enable a better understanding of the global hydrospheric cycle. These data sets include field measurements, parameters simulated from land surface models, and products derived from many satellite instruments.

NASA is mandated by Congress to make its data and products available to the broader user community. The Hydrology Data and Information Services Center (HDISC) was developed as part of the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) to archive and support data products generated by the GSFC HSB.

HDISC is a portal to a hydrology-specific, on-line, easy-access archive and distribution system, employing data analysis and visualization, data subsetting, and other user-requested techniques for better science data usage. HDISC provides convenient access to hydrology data and information from various land surface models. The first products hosted are outputs from the Global Land Data Assimilation System (GLDAS) (Rodell et al., 2004). The HDISC has the capability to support more hydrology data products and more advanced analysis tools. The goal is to develop HDISC as a data and services portal that supports weather and climate forecast, and water and energy cycle research. The following sections will introduce the GLDAS project and the data set, and the means to access the data set through HDISC.

BACKGROUND ABOUT THE GLDAS

GLDAS drives multiple offline (not coupled to the atmosphere) land surface models, integrates a huge quantity of observation based data, and executes globally at 2.5° to 1 km resolutions, enabled by the Land Information

System (LIS) (Kumar et al., 2006). Currently, GLDAS drives four land surface models: Mosaic, Noah, the Community Land Model (CLM), and the Variable Infiltration Capacity (VIC). GLDAS products include land surface state (e.g., soil moisture and surface temperature) and flux (e.g., evaporation and sensible heat flux) parameters. The temporal resolution for the GLDAS products is 3-hourly. Monthly products are also generated through temporal averaging of the 3-hourly products. For example, the total evapotranspiration for April 1979 is the average 3-hour mean rate of evapotranspiration over all the 3-hour intervals in April 1979. Output files from these four models are briefly described here. Table 1 lists some basic characteristics of the GLDAS data.

Table 1. Basic characteristics of the GLDAS data.

Contents	Water and energy budget components, forcing data
Latitude extent	-60° to 90°N
Longitude extent	-180° to 180°E
Spatial resolution	0.25°, 1.0°
Temporal resolution	3-hourly or monthly
Temporal coverage	January 1, 1979 to present for the 1.0° data February 24, 2000 to present for the 0.25° data
Dimension	360 (lon) x 150 (lat) for the 1.0° data 1440 (lon) x 600 (lat) for the 0.25° data
Origin (1st grid center)	(179.5W, 59.5S) for the 1.0° data (179.875W, 59.875S) for the 0.25° data
Land surface models	CLM 2.0 (1.0°) MOSAIC (1.0°) NOAH 2.7.1 (1.0°) VIC water balance (1.0°) NOAH 2.7.1 (0.25°)

The data used by LIS include parameter data and forcing data. All simulations were initialized on model date January 1, 1979 using soil moisture and other state fields from the respective LSM climatology for that day of the year. The 1.0 degree resolution data range from 1979 to present for the four models. The 0.25 degree data cover 2000 to present from the NOAH model. The forcing data set combines multiple data sets for the period of January 1, 1979 to present:

1979-1993: bias-corrected ECMWF Reanalysis data (Berg et al., 2003)
1994-1999: bias-corrected NCAR Reanalysis data (Berg et al., 2003)
2000: NOAA/GDAS atmospheric analysis fields
2001-2007: a combination of NOAA/GDAS atmospheric analysis fields, spatially and temporally disaggregated NOAA Climate Prediction Center Merged Analysis of Precipitation (CMAP) fields, and observation based downward shortwave and longwave radiation fields derived using the method of the Air Force Weather Agency's AGRicultural METeorological modeling system (AGRMET)

In NOAH (0.25°), snow cover data derived from the MODIS sensor aboard NASA's Terra satellite were assimilated in order to constrain the modeled snow water equivalent (SWE), using the updating technique described by Rodell and Houser (2004). SWE was adjusted when and where there was a discrepancy between the modeled SWE state (snow or no snow) and the MODIS snow cover state. A quantity of 10 mm SWE was added to pixels where the model did not have snow but the fractional MODIS snow cover was greater than 40%. Snow was removed from model pixels where MODIS indicated fractional snow cover was less than 10%.

GLDAS DATA SET IN HDISC

Current GLDAS data hosted at HDISC include a set of 1.0° data products, covering 1979 to the present, from the four models and a 0.25° data product, covering 2000 to the present, from the Noah model. The GLDAS LSM

data were created using the GRIdded Binary (GRIB) format. GLDAS applies user-defined parameter tables for the GRIB files. Table 2 shows a list of parameters provided in the GRIB files. This table shows the GRIB Product Definition Section (PDS) ID and the corresponding parameter name.

Table 2. Geophysical parameters generated from the GLDAS project.

PDS IDs	Full Name	Unit
001	Surface pressure	Pa
011	Near surface air temperature	K
032	Near surface wind magnitude	m/s
051	Near surface specific humidity	kg/kg
057	Total evapotranspiration	kg/m^2
065	Snow water equivalent	kg/m^2
071	Total canopy water storage	kg/m^2
085	Average layer soil temperature	K
086	Average layer soil moisture	kg/m^2
099	Snowmelt	kg/m^2/s
111	Net shortwave radiation	W/m^2
112	Net longwave radiation	W/m^2
121	Latent heat flux	W/m^2
122	Sensible heat flux	W/m^2
131	Snowfall rate	kg/m^2/s
132	Rainfall rate	kg/m^2/s
138	Average surface temperature	K
155	Ground heat flux	W/m^2
204	Surface incident shortwave radiation	W/m^2
205	Surface incident longwave radiation	W/m^2
234	Subsurface runoff	kg/m^2
235	Surface runoff	kg/m^2

DATA READING AND INTERPRETATION

To handle the GLDAS GRIB data, WGRIB, GrADS, or other GRIB readers are required. WGRIB is a program to manipulate, inventory, and decode GRIB files (http://www.cpc.ncep.noaa.gov/products/wesley/wgrib.html). WGRIB version 1.7.X is recommended to avoid any possible discrepancies caused by different WGRIB versions. The Grid Analysis and Display System (GrADS) is an interactive desktop tool for easy access, manipulation, and visualization of earth science data (http://grads.iges.org/grads/). Examples of using the GrADS to read the GLDAS data are shown in Figures 1 and 2, respectively. Figure 1 shows the 0.25 degree 3-hourly top layer soil moisture (0-10 cm) simulated from the Noah model at 00Z, May 1, 2007. Figure 2 shows the 1.0 degree monthly top layer soil moisture (0-2 cm) simulated from the Mosaic model in May, 2007.

GRIB files identify the contents (e.g., soil moisture, temperature) by parameter numbers. These numbers are linked to their respective parameter names in a parameter table. The GLDAS data set applies a user-specific parameter table for each model to indicate the content and parameter number. Users need to set the specific parameter table before using any GRIB reader.

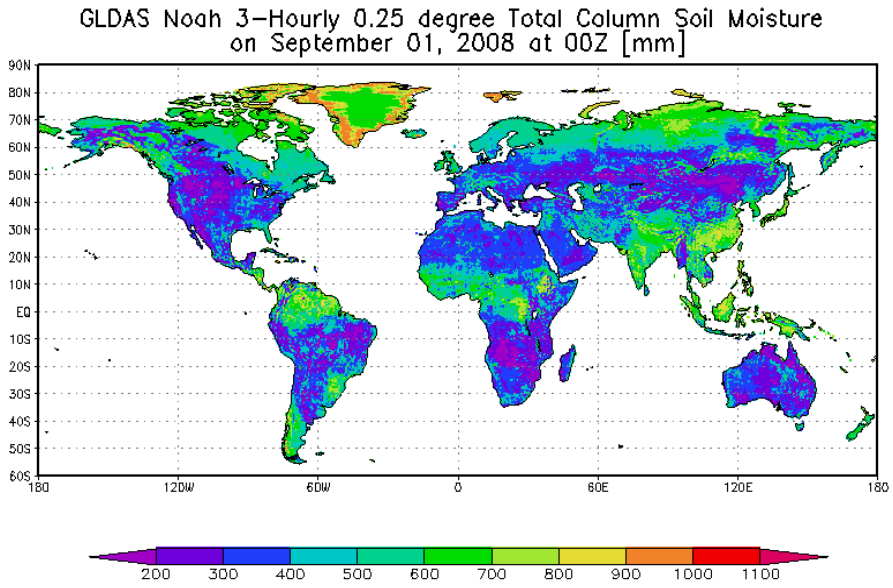

Figure 1. Global 0.25 degree 3-hourly total column soil moisture (0-200 cm) simulated from the Noah model at 00Z, September 1, 2008

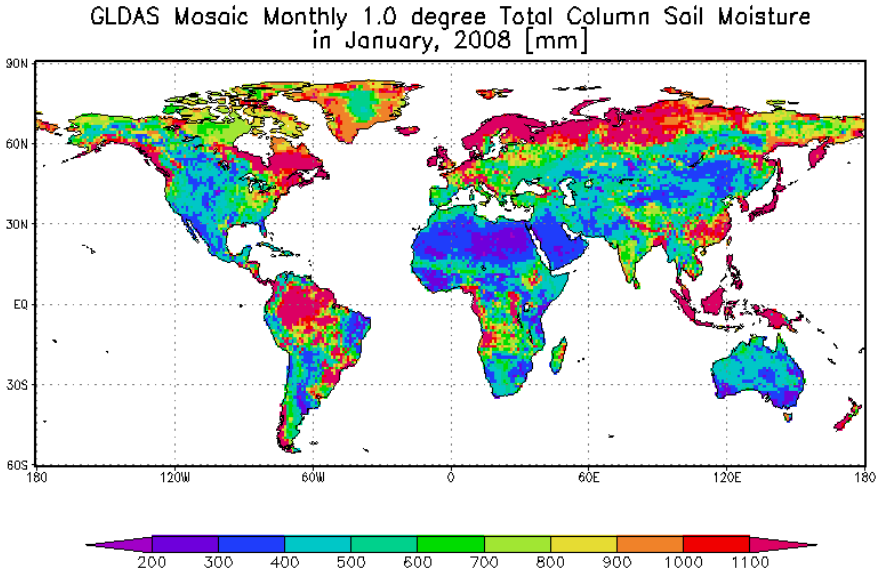

Figure 2. The 1.0 degree monthly total column soil moisture simulated from the Mosaic model in January, 2008.

The number of vertical levels for soil moisture (SoilM) is model specific. The generic GRIB table defines the different soil layers as SoilM1, …, Soil*MN*, respectively, where *N* is the number of soil layers. Table 3 lists the depths of soil layers used in different land surface models. Terrestrial water storage is the sum of soil moisture in all layers, accumulated snow, and plant canopy surface water. Total precipitation is the sum of rainfall and snowfall and the total runoff is the sum of subsurface runoff and surface runoff.

Table 3. The depth of soil layers used in different land surface models.

CLM 2.0 (10 layers)	
Depths	0-0.018, 0.018-0.045, 0.045-0.091, 0.091-0.166, 0.166-0.289, 0.289-0.493, 0.493-0.829, 0.829-1.383, 1.383-2.296, and 2.296-3.433 m.
MOS (3 layers)	
Depths	0-0.02,0.02-1.50, and 1.5-3.50 m.
NOAH (4 layers)	
Depths	0-0.1, 0.1-0.4, 0.4-1.0, and 1.0-2.0 m.
VIC (3 layers)	
Depths	0-0.1, 0.1-1.6, and 1.6-1.9 m.

ACCESS HDISC DATA

The HDISC maintains archives of all GLDAS data products. The data are publicly available. The archived data can be accessed via anonymous ftp network transfer. The GLDAS data holding and ftp downloading interface is shown in Figure 3. The 3-hourly GLDAS data can be downloaded directly via the GES DISC anonymous ftp: ftp://agdisc.gsfc.nasa.gov/data/s4pa/GLDAS_SUBP/. The monthly GLDAS data can be downloaded from ftp://agdisc.gsfc.nasa.gov/data/s4pa/GLDAS/

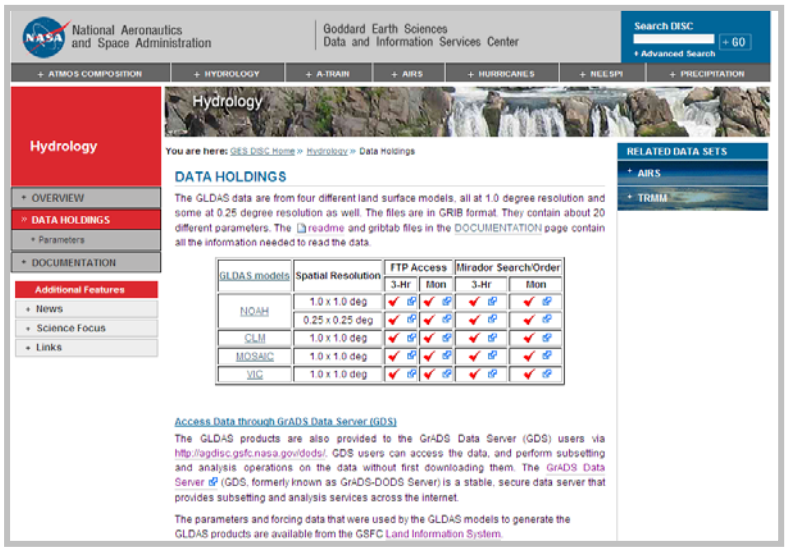

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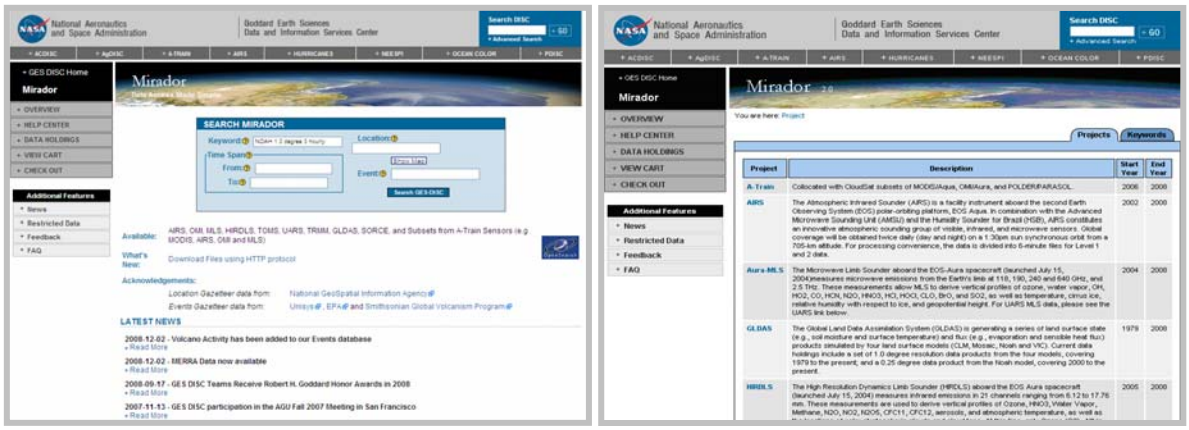
Figure 3. HDISC data holding and ftp downloading page

Search and Access System

In addition to the basic anonymous data downloading, HDISC provides several advanced data search and downloading services, such as Mirador (Figure 4). Mirador, a Spanish word for a window offering an extensive view, is a Google-based search tool that provides keywords searching of Earth science data at the NASA GES DISC. In the Mirador interface, GLDAS data can be searched through a keyword (e.g., Noah) and the time span (Figure 4a). Once the list of data products is shown in the interface, users can download GLDAS data in batch mode

The Mirador search and order tool is currently under enhancement by using the new semantic web technology. Multiple views of project, instrument, earth science parameter, and application will be available in Mirador. For the GLDAS products, and quickly navigate down the hierarchical path to find data of interest (Figure 4b). The key semantic technology behind these tree structures is an ontology based on the Global Change Master Directory (GCMD) Directory Interchange Format (DIF). Mirador's semantic infrastructure, once fully realized, will enable interoperability with other semantically based hydrological data discovery and service frameworks.



(a) (b)

Figure 4. Search and order GLDAS products either in Mirador keyword search interface (a) or in the guided navigation interface (b)

Access GLDAS products through the GrADS Data Server (GDS)

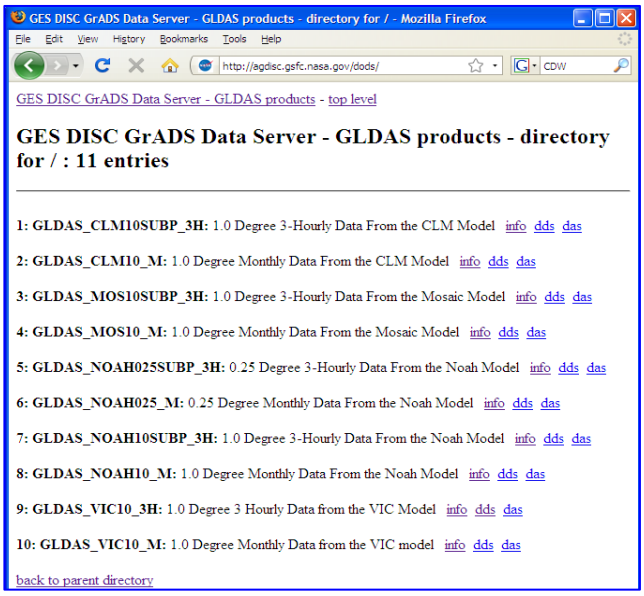


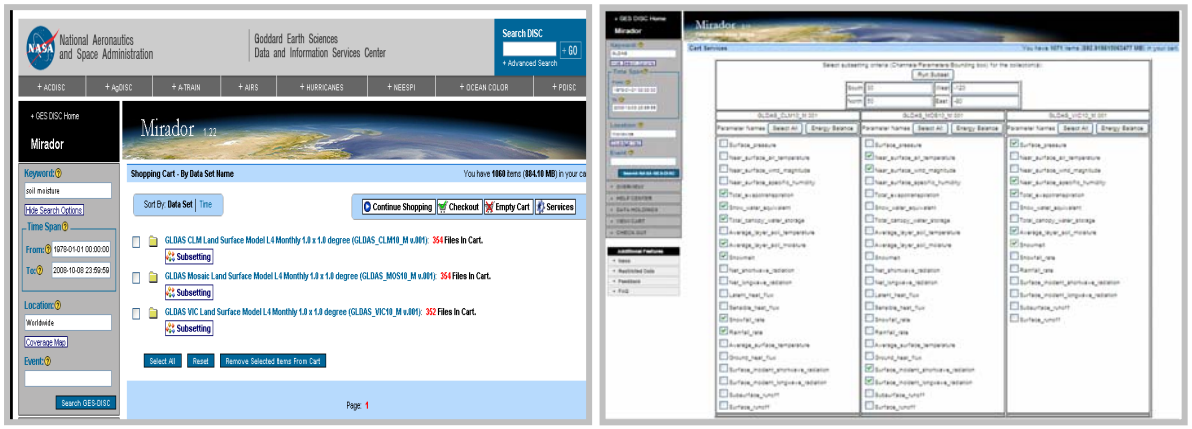
Figure 5. The HDISC GrADS Data Server (GDS) interface for the GLDAS products

The GrADS Data Server (GDS) is a stable, secure data server that provides subsetting and analysis services across the internet. The core of the GDS is OPeNDAP (formerly DODS), a software framework used for data networking that makes local data accessible to remote locations. The GLDAS products are provided to the GDS users via http://agdisc.gsfc.nasa.gov/dods/. Figure 5 shows the HDISC GDS page, which has links to various GLDAS products. GDS users can perform subsetting and analysis operations without first downloading data. The GDS subsetting capability allows users to retrieve a specified temporal and/or spatial subdomain from a large data set. The GDS analysis capability allows users to retrieve the results of an operation applied to one or more data sets on the server. The GDS supports any operation that can be expressed in a single GrADS expression, including basic math functions, averages, smoothing, differencing, correlation, and regression.

HDISC DATA SERVICES

On-The-Fly Spatial and Parameter Subset

The GLDAS products can be subsetted by parameter and spatial region. Users can search and order the GLDAS products by user-selected parameter and spatial region, before downloading them from the Mirador search and order tool. For example, a user selects three GLDAS data sets from the Mirador tool (Figure 6a). And then, the user selects the parameter(s) and spatial region of interest to subset (Figure 6b). Finally, the user runs the subset service and downloads the subsetted data on the fly. The subsetted data are in the GRIB format, same as that of the original GLDAS products.

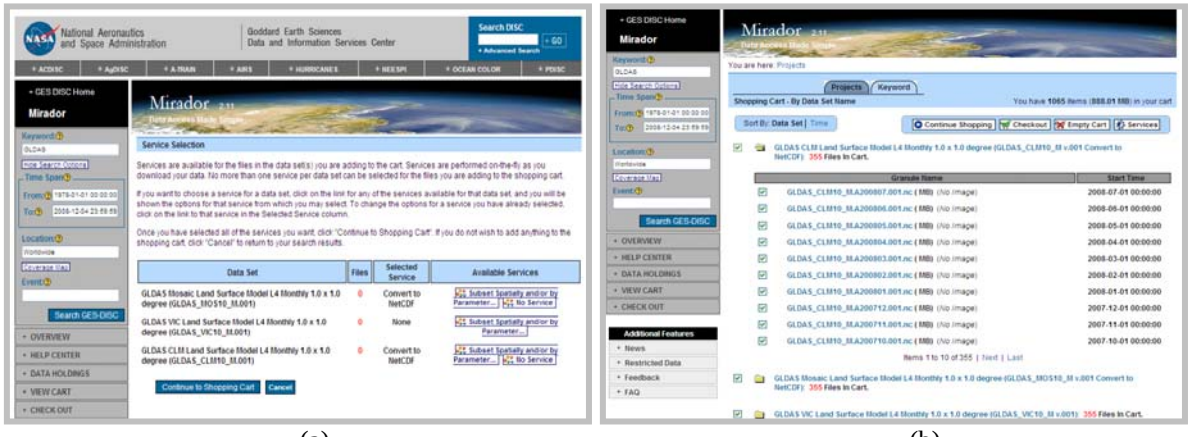


(a) (b)

Figure 6. Example of a user selecting GLDAS data sets (a) and the spatial region and parameters to perform an on-the-fly subset

On-The-Fly Conversion to NetCDF

NetCDF (network Common Data Form) is a self-describing, machine-independent format for representing scientific data. This format is widely used in the earth science community. To accommodate netCDF users, HDISC has developed an on-the-fly GRIB to netCDF formation conversion service. A user can choose whether he wants the original GRIB format or the netCDF format. Figure 7 gives an example of the netCDF conversion function at the data set and granules levels, respectively.

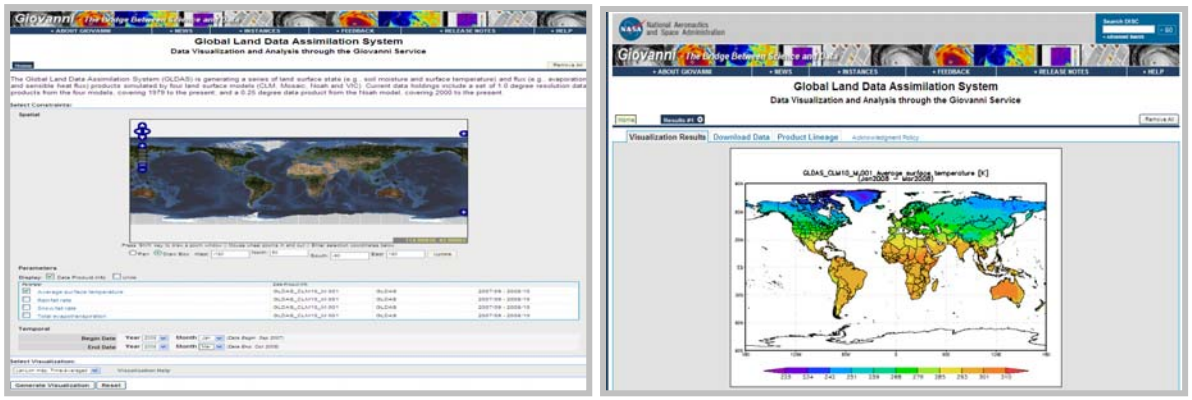


(a) (b)

Figure 7. Download GLDAS products in the netCDF format. (a) or in the guided navigation interface (b)

Online Visualization and Analysis in Giovanni

Giovanni is an online application developed by the GES DISC that allows researchers to rapidly explore data, so that spatial-temporal variability, anomalous conditions, and patterns of interest can be directly analyzed online before optional downloading of higher resolution data (http://disc.sci.gsfc.nasa.gov/techlab/giovanni/). Giovanni is comprised of a number of interfaces, called instances, each tailored to meet the needs of different Earth science research communities. HDISC is developing a GLDAS instance in Giovanni (Figure 8a). Data from all GLDAS models will soon be available for the science community. Figure 8b shows an example of Giovanni visualizations, the mean surface temperature simulated from the CLM model from January to March, 2008.



(a) (b)

Figure 8. Online visualization and analysis in Giovanni (a) sample result (b)

Application of the GLDAS Products

Terrestrial Hydroclimatology

The long term, global, multi-model GLDAS data are used to develop climatology of water cycle components for each continental to global scale region. The climatology will serve as a baseline for water cycle and climate change studies as well as model assessments. Annual mean input (precipitation), output (evapotranspiration and runoff), and terrestrial storage amplitude (soil moisture and snow) are computed and averaged over the four GLDAS-driven models. Spread among the models gives uncertainty estimate. Figure 9 shows climatology and uncertainty by continent, as equivalent heights of water (cm = 10 kg/m²) based on 1979-2007 output from four models.

Teleconnections of droughts and pluvial

The focus of this study is two folds. One is to characterize the movements and time lag of dry and wet anomalies over the globe, and the other is to explore teleconnections between remote regions of the globe and relationship with phenomenon such as El Niño/Southern Oscillation. An example of possible teleconnection is seen where large terrestrial water storage anomaly in western coastline of Gulf of Mexico is followed by large precipitation anomaly in the Plains of the U.S. a few month later.

Future HDISC direction

HDISC will provide daily GLDAS products through time-averaging of the current 3-hourly data set. The GLDAS data will also be provided on Google Earth to facilitate scientific research. The next suite of products to be hosted at HDISC is that from the North America Land Data System (NLDAS). The NLDAS products include four LSMs executed in uncoupled mode with common hourly surface forcing using a 1/8º grid over the continental United States (Mitchell et al., 2004; http://ldas.gsfc.nasa.gov/). Users can access the HDISC website for the latest GLDAS data and HDISC news (http://disc.gsfc.nasa.gov/hydrology/).

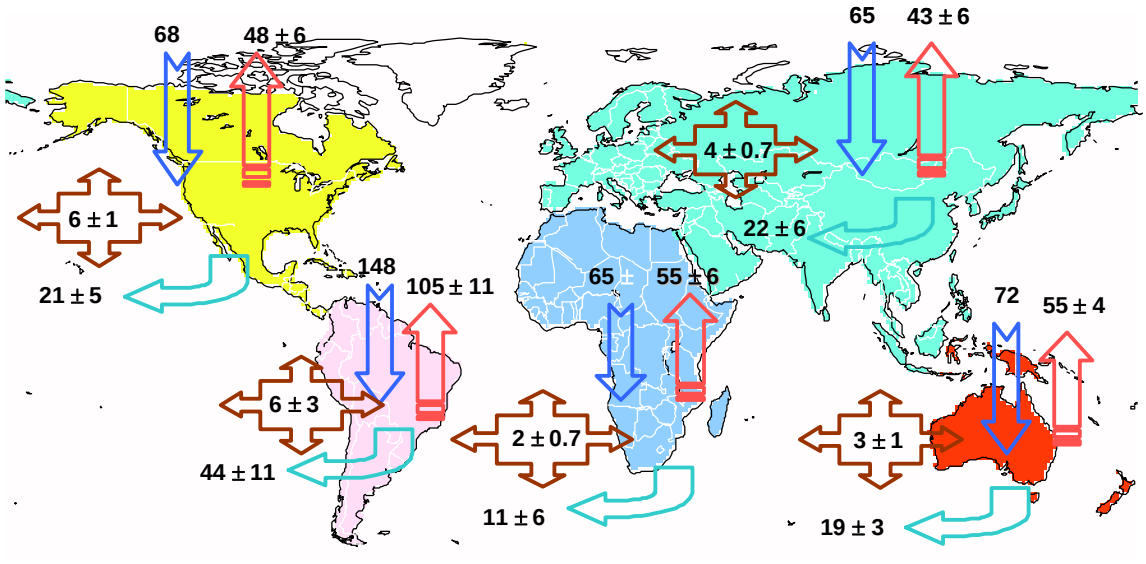


Figure 9. Annual mean water cycle components by continent in (cm) based on 1979-2007 from four GLDAS-driven models. Arrows and numbers correspond to precipitation (blue), evapotranspiration (red), total runoff (light blue), and amplitude (range/2) of terrestrial water storage (brown). Greenland and islands in Arctic are excluded in the computation.

Acknowledgement

The Global Land Data Assimilation System (GLDAS) project is funded by NASA's Energy and Water Cycle Study (NEWS) Program.

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